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Long Range Weather Forecasting:
A Brief Statement

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Long-range Weather Forecasting

Although the purpose of this paper is to discuss longer-range weather forecasting and projection of climate fluctuations, by placing these problems in the setting of the whole spectrum of weather forecasting we can better explain the special problems the longer ranges pose. Public forecasts are regularly issued for periods of from a few hours up to 90 days. There are even some warnings issued with lead times of minutes in the case of tornadoes bearing down on towns and cities. The latter are sometimes disseminated by heroic measures: bulletins interrupting scheduled TV and radio programs, civil defense warning sirens, and police cars cruising city streets.

Forecasts in the various ranges differ in accuracy and detail of information. A measure of the detail provided in the forecasts would be the sheer bulk of information provided all users. There is no ready figure for this, but for comparing detail of forecasts in the various ranges, the amount of information transmitted from the National Meteorological Center (NMC) on the nationwide weather telecommunications networks will do. The information is in the form of maps on which various weather parameters are charted, and messages both in worded form (alphabetics) and numerically coded form (numerics). The charts are transmitted by <u>facsimile</u>, which is a telecommunications system enabling the reproduction of transmitted charts at the receiving stations. Alphanumerics are transmitted on teletypewriter circuits. Although many governmental agencies and private and industrial organizations now have receivers connected to the networks, the original purpose, and perhaps still the most important purpose, of the networks is quick communication of information among the 52 Forecast Offices and 250 local Service Offices of the National Weather Service. The information transmitted by NMC on the networks consists of information about the current and predicted state of the atmosphere. It is principally used by the 300-odd offices as guidance in preparing forecasts for the general public and many specialized users.

The most detailed set of forecast information is for periods of from 12 hours to 3 days. These are issued locally several times daily, and are essentially forecasts for all local areas of the U. S. of the sequence in time of temperature, wind, cloudiness, rainfall, snowfall, and other forms of precipitation. The bulk of information from NMC is staggering by yesteryear's standards. NMC guidance for the several hundred forecasters all over the country consists of about 500 facsimile charts daily and a half million teletype groups (a group is five alphanumeric characters).

As the lead time gets longer, the amount of information and the detail in the forecasts dramatically decreases. NMC guidance for forecasts 3, 4, and 5 days in advance consists of 15 facsimile charts and 250 teletype groups daily. Although nominally the charts are for a specific time of day, they are interpreted as being merely typical for the 24 hour period.

For days 6-10, a set of three charts and 300 teletype groups are issued from NMC as guidance three times a week. The charts give only averages over the five days of circulation, temperature, and precipitation. The temperature forecasts are given in five categories: normal, and above, much above, below, and much below. Precipitation is given in three categories: heavy, light, and moderate, all relative to the normal.

The thirty-day outlook, as it is called, consists of a four-page publication distributed by mail. There are three charts for North America containing forecast information, and three similar charts for Europe and Asia. The North American charts are also distributed by facsimile. These "forecasts," issued twice monthly, are for 30-day averages of temperature and precipitation. Forecasts are in three categories for temperature (above, below, and near normal), and in two categories for precipitation (light and heavy, both relative to normal). The skill is low, although detectable and by users' accounts useful. Whereas "no forecast" (climatology) yields a 33% chance for each category, the thirty-day outlook changes this to 40%.

The seasonal, 90-day, outlooks are similar to those for thirty days. Only one chart of temperature forecasts is issued, however, in two categories--above and below normal. There is a third category, which in effect is "no forecast," for those areas where the odds are too close to call. Predictions of precipitation are made, but have no detectable significant skill, so are not issued. They are made experimentally, with the view to improving them to the point of usefulness. The seasonal forecasts are issued four times annually.

The progressive lack of detail and information in the predictions as forecasts are made farther in advance is not due to users' needs and demands, nor arbitrary management decisions, nor lack of material resources. This characteristic of the public service is due to fundamentals of the forecasting problem itself. It is a characteristic that will remain with the system no matter what is done.

Forecasts in all ranges and our ability to improve them, are limted by three things:

1. Data. Information about the state of the atmosphere and its environment (the hydrosphere, solid earth, and space) is limited. In part this is due to lack of resources, in part by the state of the art in the technology of observing.

2. Our understanding of the physical processes involved and our knowledge of the appropriate methodologies and equations. Relaxation of this limitation is largely a matter of time, for it involves the unknown, and therefore research and learning. The pace is affected by the amount of effort devoted to it, however.

3. Our capability to process information in a timely fashion. This limitation involves availability of manpower, state-of-the-art in computer technology, and the manageability of the data processing problem itself. Advances during the past 20 years have come from spectacular breakthroughs in computer power, and increased computer power remains a great hope for forecast improvement.

When we consider extending the lead time of forecasts, however, a fourth "limitation" comes into play--that of the degree of fundamental determinism in the physical system with which we are dealing. We can make accurate, highly detailed forecasts, including trends, for today and tomorrow. We cannot do so for a particular day more than five days in advance. Will we ever be able to forecast weather accurately and in detail for a particular day, say, a season ahead? The answer is no, unless some entirely unknown and unforeseen physical or mathematical principle is discovered. Such a principle may not exist, its discovery cannot be planned, and it would impact meteorology in a way that the discovery of radioactivity impacted physics. If and when a discovery like that is made, we can be sure it will be known to us and used. It would be a strange scientist indeed who could keep such a discovery to himself, even for his personal benefit.

Our present understanding is that the atmosphere is fundamentally unpredictable to a degree, independent of how much we learn or how many resources are devoted to the forecast problem. The problem is far from hopeless, however. We are not at the limit of predictability, and some improvements can surely be made.

As reflected in the present public service, the fundamental predictability of the atmosphere (accuracy and detail) varies inversely with lead time. As the lead time increases, the accuracy and detail, reflected in the amount of information disseminated, decreases. There is a trade-off between accuracy and detail. For example, a forecast of tomorrow's mean temperature over the Metropolitan Area would be more accurate than a forecast of the temperature at Washington National Airport at noon tomorrow. Similarly, if we were to forecast whether the last 15 days of a thirty-day period would be warmer, compared to normal, than the first 15 days, our skill, or accuracy, might well be missing altogether with today's system.

We are coming to the concept that there are "natural" periods of the atmosphere and its environment for the purposes of forecasting. About one week is such a natural period, it being typical of the time it takes for certain cycles to take place. One reasonably homogeneous air mass is replaced by another in about a week's time, and it takes about a week for one storm to follow another. Thus five days was selected as a suitable period to average over for the 6-10 day forecasts. Ninety days is also a natural period, it being about the length of summers and winters and also the periods of transition between the warm and cold seasons. Thirty-days is not a natural period, but was chosen because of the usefulness of outlooks for such a period. This is reflected in the fact that the thirty- and ninety-day temperature outlooks have similar skill, in spite of the general predictability principles already discussed. Forecasts of above or below normal temperature for the two periods, each have a probability of 60-65% of having the correct sign.

A period of thirty days is likely to be influenced by such events as the odd storm or cold wave, which are unpredictable in that range. An average for ninety days is less influenced by such a single event, and there is more opportunity for a counter-balancing occurrence. Furthermore a ninety-day period provides a better opportunity for longer-term slowly acting influences to affect the outcome. Among the most likely candidates are ocean surface temperature anomalies. Ninety days is also a highly useful period in terms of user needs. It is roughly the length of the growing season, and also the period of stress on energy producing and distribution systems, e. g., electricity for summer air conditioning and gas, oil, and coal for winter heating.

A year (365 days) is neither a natural period, nor would predicted averages for such a period be particularly useful. For example, a year predicted to be "normal" might indeed turn out to be "normal," but on the other hand might be composed of an unusually warm summer and a counter-balancing unusually cold winter. A forecast of such normalcy even when correct would be of little use to anyone, and indeed would be downright misleading to managers of energy.

Much is being done already about predicting climate fluctuations, defined here as means and variance over periods of from a month to a millenium. In the past the efforts have been by individual groups of scientists scattered all over the world. Without the real and present needs of users, they have had a strong research and academic flavor, with little emphasis on real service. With the rapidly growing world-wide problems of energy, food, and water supply, this is changing. The World Meteorological Organization is in the process of organizing the World Climate Program to provide international leadership and coordination. The U. S. has developed the U. S. Climate Plan, and national agencies have developed plans for their individual roles in the whole. For example, there is the NOAA Climate Program (December 1977) and the Proposed NASA Contribution to the Climate Program (July 1977).

With the lead role to be played by NOAA in its Climate Program Office, ongoing national efforts will be coordinated and augmented and new efforts will be started. Among ongoing national efforts are the thirty and ninety-day outlooks already discussed, extensive dynamical modeling efforts at NOAA's Geophysical Fluid Dynamics Laboratory, the National Center for Atmospheric Research, and a few other places. Statistical aspects of climate, and the physical effects of the hydrosphere, cryosphere, solid earth, and outer space upon it, are being studied at many places; the programs at Scripps Institute, the University of Wisconsin, University of California at Los Angeles, and Oregon State University being a few examples. NASA has recently organized the Goddard Laboratory for Atmospheric Sciences with a major emphasis on climate studies including both statistical and dynamical modeling. NOAA's Center for Climatic and Environmental Assessment (CCEA) provides help to many governmental agencies and private and industrial organizations in interpreting climate fluctuations in terms of their effects on crops, water supply, and energy production and distribution.

Of prime interest to the National Weather Service (NWS) is the Climate Analysis Center (CAC), which is presently being organized and staffed within NWS. This is one of the two service units in the national plan, the other being CCEA. The CAC will produce information on climate fluctuations, both current and projected, in meteorological terms (temperature, precipitation, etc.). Its prime data source will be the real-time data banks of the National Meteorological Center. The CCEA will be a principal user of CAC's information in its impact assessment. The CAC will include a development staff to work on improvement of its products, and will both do original work, and translate research results obtained elsewhere into operational practice.

The central focus of CAC will be on seasonal forecasting. Besides dealing with a natural period of economic significance, the seasonal forecast has the advantage of being an existing product whose general uses, capability, and limitations users are already familiar with. The problems to be attacked boil down to extension of lead time, increase in accuracy, and perhaps providing more detail. The present lead time is five or six days before the period begins. The accuracy of the two categories, above and below normal, is 60-65% correct. Reasonable goals are to increase the accuracy to 75% with the present lead time and detail, and to increase the lead time with present accuracy to 3 to 9 months. Lead times beyond these are neither likely to be achieved in the next decade, nor would they be as useful. Concentration of resources should take into account the time in which users could or would react to the information.

Large dynamical models have been very successful in improving the accuracy of forecasting in ranges up to 10 days. They have also greatly contributed to our understanding of atmospheric and oceanic processes underlying climate. Indeed dynamical modeling may turn out to be the ultimate tool for projecting climate fluctuations. Realization of their promise for this use, however, appears to be many years away. Since the CAC will concentrate on development of techniques for implementation within 2-5 years, it will have no program in dynamical modeling. Instead it will concentrate on empirical and statistical investigations and techniques, in working to improve the accuracy and increase the lead time of seasonal forecasts.

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